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STATEMENT

I, Yasuhide KOBAYASHI, residing at 2-24-12, Hachimanyama, Setagaya-ku, Tokyo, Japan, hereby state that I have a thorough knowledge of the English and Japanese languages and that the attached document is an accurate English translation of the Japanese specification of Japanese Patent Application No. 2000-89274 filed March 28, 2000, upon which the present application claims a priority.

Declared at Tokyo, Japan

This 14th day of August, 2003

A handwritten signature in black ink, appearing to read "Y. Kobayashi", with a long, sweeping horizontal stroke extending to the right.

Yasuhide Kobayashi

PATENT OFFICE
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This is to certify that the annexed is a true copy of the following application as filed with this Office.

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Application Number: Japanese Patent Application
No. 2000-089274

Applicant(s): FUJI PHOTO FILM CO., LTD.

April 13, 2001

Commissioner,

Patent Office: Kozo OIKAWA (Seal)

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[List of Documents]

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| [Name of Document] | Specification | 1 copy |
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[Designation of Document] Specification

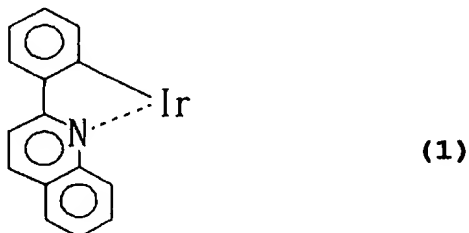
[Title of the Invention]

HIGH EFFICIENCY RED LIGHT-EMITTING ELEMENT, LIGHT-EMITTING
MATERIAL COMPRISING IRIDIUM COMPLEX AND NOVEL IRIDIUM COMPLEX

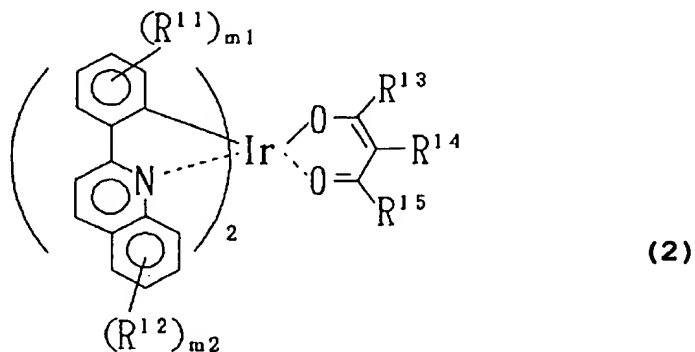
[Claims]

1. An organic light-emitting element having an external quantum efficiency of 5% or more and λ_{max} of 590 nm or more.

2. A light-emitting element material comprising a compound having a partial structure represented by the following general formula (1):



3. A compound represented by the following general formula (2):



wherein R^{11} and R^{12} each represent a substituent; R^{13} , R^{14} and R^{15} each represent a hydrogen atom or substituent; m^1 represents an integer of from 0 to 4; and m^2 represents an integer of from 0 to 6.

4. A light-emitting element comprising a light-emitting layer or a plurality of thin organic compound layers containing a light-emitting layer provided interposed between a pair of electrodes, characterized in that at least one of said plurality of layers comprises at least one of the compounds according to Claim 2 or 3 incorporated therein.

5. The light-emitting element according to Claim 4, wherein said layer comprising a compound according to Claim 2 or 3 incorporated therein is formed by a coating process.

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention Belongs]

The present invention relates to a light-emitting material and light-emitting element capable of converting electric energy to light which is then emitted and more particularly to a light-emitting element which can be preferably used in various arts such as display element, display, backlight, electrophotography, illuminating light source, recording light source, exposure light source, reading light source, sign, advertising display and interior.

[0002]

[Prior Art]

Today, various display elements have been under active study and development. In particular, an organic electric field light-emitting (EL) element can emit with a high luminance at a low voltage and thus has been noted as a favorable display element. For example, a light-emitting element having a vacuum-deposited thin organic layer has been known (Applied Physics Letters, vol. 51, page 913, 1987). The light-emitting element described in this reference comprises as an electron-transporting material tris(8-hydroxyquinolate) aluminum complex (Alq) which is laminated with a positive hole-transporting material (amine compound) to exhibit drastically improved light-emitting properties as compared with the conventional single-layer type elements.

In recent years, the application of organic EL element to color display has been under active study. However, in order to develop a high performance color display, it is necessary that the properties of blue, green and red light-emitting elements be each improved.

[0003]

As a means for improving the properties of light-emitting elements there has been reported a green light-emitting element utilizing the emission of light from orthometalated iridium complex ($\text{Ir}(\text{ppy})_3$: Tris-Ortho-Metalated Complex of Iridium (III) with 2-Phenylpyridine) (Applied Physics Letters 75, 4

(1999)). The foregoing element can attain an external quantum yield of 8%, which is higher than the limit of the external quantum yield of the conventional light-emitting elements, i.e., 5%. However, since the foregoing light-emitting element is limited to green light-emitting element, the range within it can be applied as a display is narrow. It has thus been desired to develop light-emitting materials capable of emitting light having other colors.

Noting a red light-emitting element, many light-emitting elements comprising DCM(4-(Dicyanomethylene)-2-methyl-6-(4-dimethylaminostyryl)-4H-pyran) and its analogy have been reported. No elements having an external quantum efficiency of more than 5% have been reported. If the external quantum efficiency of 5%, which is considered to be the limit of the external efficiency of the conventional red light-emitting element, can be surpassed, the development of high efficiency organic EL devices capable of emitting light having various colors can make a great progress. It has thus been desired to develop such high efficiency organic EL elements.

[0004]

[Problems that the Invention is to Solve]

An object of the present invention is to provide a red light-emitting element having good light-emitting properties, and a light-emitting material which can form such a

light-emitting element.

[0005]

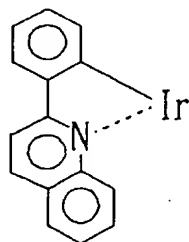
[Means for Solving the Problems]

The foregoing object of the invention can be accomplished by the following means.

1. An organic light-emitting element having an external quantum efficiency of 5% or more and λ_{max} of 590 nm or more.

2. A light-emitting element material comprising a compound having a partial structure represented by the following general formula (1):

[0006]

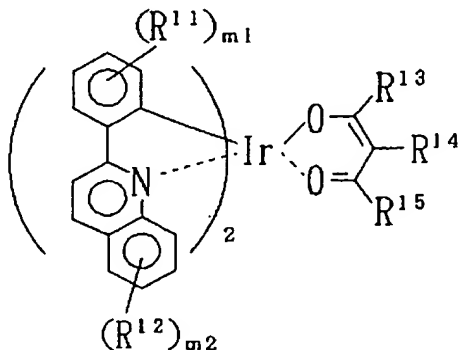


(1)

[0007]

3. A compound represented by the following general formula (2):

[0008]



(2)

[0009]

wherein R^{11} and R^{12} each represent a substituent; R^{13} , R^{14} and R^{15} each represent a hydrogen atom or substituent; m^1 represents an integer of from 0 to 4; and m^2 represents an integer of from 0 to 6.

4. A light-emitting element comprising a light-emitting layer or a plurality of thin organic compound layers containing a light-emitting layer provided interposed between a pair of electrodes, characterized in that at least one of the plurality of layers comprises at least one of the compounds according to Clause 2 or 3 incorporated therein.

5. The light-emitting element according to Clause 4, wherein the layer comprising a compound according to Clause 2 or 3 incorporated therein is formed by a coating process.

[0010]

[Mode for Carrying Out the Invention]

The present invention will be further described hereinafter.

The light-emitting element is an organic light-emitting element having an external quantum efficiency of 5% or more and λ_{max} of 590 nm or more. The organic light-emitting element to be used herein is not specifically limited. In practice, however, an organic EL (electroluminescence) element.

The external quantum efficiency of the light-emitting element of the invention is preferably 7% or more, more

preferably 9% or more, even more preferably 11% or more, particularly 15% or more.

The light-emitting element of the invention emits light having λ_{max} of preferably 593 nm or more, more preferably 596 nm or more, even more preferably 599 nm or more from the standpoint of purity of red color.

[0011]

The light-emitting element of the invention is preferably an element comprising a transition metal complex (preferably orthometalated complex), more preferably an iridium complex or platinum complex, even more preferably an orthometalated iridium complex, particularly a compound having a partial structure represented by the following general formula (1).

"Orthometalated metal complex" is a generic term for a group of compounds as described in Akio Yamamoto, "Yuki Kinzoku Kagaku- Kiso to Oyo- (Organic Metal Chemistry - Fundamentals and Application)", Shokabosha, pp. 150, 232, 1982, H. Yersin, "Photochemistry and Photophysics of Coordination Compounds", Springer-Verlag, pp. 1 - 77, pp. 135 - 146, 1987, etc.

[0012]

The light-emitting element of the invention preferably comprises a layer comprising a compound having an ionization potential of 5.9 eV or more (more preferably 6.0 eV or more), more preferably an electron-transporting layer having an ionization potential of 5.9 eV or more, provided interposed

between the cathode and the light-emitting layer.

The CIE chromaticity value x of light emitted from the light-emitting element of the invention is preferably 0.50 or more, more preferably 0.53 or more, even more preferably 0.57 or more, particularly 0.60 or more from the standpoint of purity of red color.

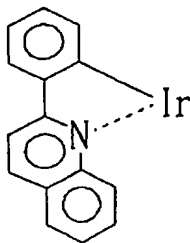
The CIE chromaticity value y of light emitted from the light-emitting element of the invention is preferably 0.50 or more, more preferably 0.45 or more, even more preferably 0.39 or more.

The half width of spectrum of emission from the light-emitting element of the invention is preferably 100 nm or less, more preferably 90 nm or less, even more preferably 80 nm or less, particularly 70 nm or less from the standpoint of purity of red color.

The compound having a partial structure represented by the general formula (1) will be further described hereinafter.

[0013]

(1)



[0014]

The valency of iridium constituting the compound having a partial structure represented by the general formula (1) is not specifically limited but is preferably 3. The foregoing compound may have one iridium atom per molecule or may be a so-called binuclear complex having two or more iridium atoms per molecule. The foregoing compound is preferably one having one iridium atom per molecule. This compound may further contain other metal atoms but preferably is a compound having an iridium complex alone.

The compound having a partial structure represented by the general formula (1) may have various ligands. Examples of the other ligands include various known ligands. Examples of these ligands include those described in H. Yersin, "Photochemistry and Photophysics of Coordination Compounds", Springer-Verlag, 1987, Akio Yamamoto, "Yuki Kinzoku Kagaku-Kiso to Oyo- (Organic Metal Chemistry - Fundamentals and Application)", Shokabosha, 1982, etc. Preferred among these ligands are halogen ligands (preferably chlorine ligand), nitrogen-containing heterocyclic ligands (e.g., phenylpyridine, benzoquinoline, quinolinol, bipyridyl and phenanthroline), diketone ligand, carboxylic acid ligand, and PF_6 ligand. Preferred among these ligands is diketone ligand.

[0015]

There may be used one or a plurality of kinds of ligands

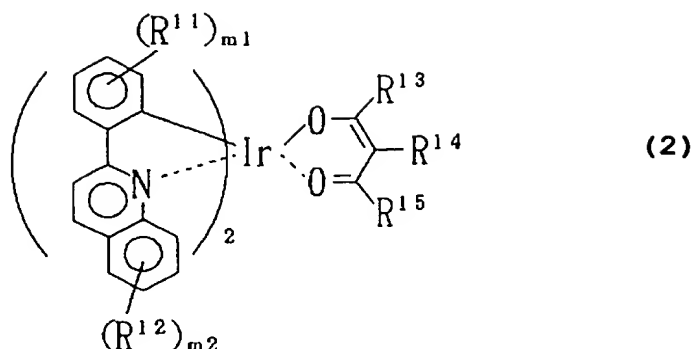
constituting the compound of the invention. The number of ligands in the complex is preferably from 1 to 3, particularly from 1 or 2, more preferably 2.

The compound of the invention may be a neutral complex or ionic complex having a counter ion (e.g., chlorine ion, PF_6 ion, ClO_4 ion), preferably neutral complex.

The number of carbon atoms in the compound of the invention is preferably from 15 to 100, more preferably from 20 to 70, even more preferably from 30 to 60.

Preferred embodiment of the compound of the invention is a compound represented by the following general formulae (2).

[0016]



[0017]

R^{11} and R^{12} each represent a substituent. R^{11} 's or R^{12} 's may be connected to own or each other to form a cyclic structure. Examples of the substituents represented by R^{11} and R^{12} include alkyl group (alkyl group preferably having from 1 to 30, more preferably from 1 to 20, particularly from 1 to 10 carbon atoms, e.g., methyl, ethyl, iso-propyl, tert-butyl, n-octyl, n-decyl, n-hexadecyl, cyclopropyl, cyclopentyl, cyclohexyl, trifluoromethyl, pentafluoroethyl), alkenyl group (alkenyl group preferably having from 2 to 30 carbon atoms, more preferably from 2 to 20 carbon atoms, particularly from 2 to 10 carbon atoms, e.g., vinyl, allyl, 2-butenyl, 3-pentenyl), alkynyl group (alkynyl group preferably having from 2 to 30 carbon atoms, more preferably from 2 to 20 carbon atoms, particularly from 2 to 10 carbon atoms, e.g., propargyl, 3-pentynyl), aryl group (aryl group preferably having from 6 to 30 carbon atoms, more preferably from 6 to 20 carbon atoms,

particularly from 6 to 12 carbon atoms, e.g., phenyl, p-methylphenyl, naphthyl, anthranyl), amino group (amino group preferably having from 0 to 30 carbon atoms, more preferably from 0 to 20 carbon atoms, particularly from 0 to 10 carbon atoms, e.g., amino, methylamino, dimethylamino, diethylamino, dibenzylamino, diphenylamino, ditolylamino), alkoxy group (alkoxy group preferably having from 1 to 30 carbon atoms, more preferably from 1 to 20 carbon atoms, particularly from 1 to 10 carbon atoms, e.g., methoxy, ethoxy, butoxy, 2-ethylhexyloxy), aryloxy group (aryloxy group preferably having from 6 to 30 carbon atoms, more preferably from 6 to 20 carbon atoms, particularly from 6 to 12 carbon atoms, e.g., phenyloxy, 1-naphthyloxy, 2-naphthyloxy), heteroaryloxy group (heteroaryloxy group preferably having from 1 to 30 carbon atoms, more preferably from 1 to 20 carbon atoms, particularly from 1 to 12 carbon atoms, e.g., pyridyloxy, pyrazolyloxy, pyrimidyloxy, quinolyloxy), acyl group (acyl group preferably having from 1 to 30 carbon atoms, more preferably from 1 to 20 carbon atoms, particularly from 1 to 12 carbon atoms, e.g., acetyl, benzoyl, formyl, pivaloyl), alkoxycarbonyl group (alkoxycarbonyl group preferably having from 2 to 30 carbon atoms, more preferably from 2 to 20 carbon atoms, particularly from 2 to 12 carbon atoms, e.g., methoxycarbonyl, ethoxycarbonyl), aryloxycarbonyl group (aryloxycarbonyl group preferably having from 7 to 30 carbon atoms, more preferably from 7 to 20 carbon

atoms, particularly from 7 to 12 carbon atoms, e.g., phenyloxycarbonyl), acyloxy group (acyloxy group preferably having from 2 to 30 carbon atoms, more preferably from 2 to 20 carbon atoms, particularly from 2 to 10 carbon atoms, e.g., acetoxy, benzoyloxy), acylamino group (acylamino group preferably having from 2 to 30 carbon atoms, more preferably 2 to 20 carbon atoms, particularly from 2 to 10 carbon atoms, e.g., acetylamino, benzoylamino), alkoxycarbonylamino group (alkoxycarbonylamino group preferably having from 2 to 30 carbon atoms, more preferably 2 to 20 carbon atoms, particularly from 2 to 12 carbon atoms, e.g., methoxycarbonylamino), aryloxycarbonylamino group (aryloxycarbonylamino group preferably having from 7 to 30 carbon atoms, more preferably 7 to 20 carbon atoms, particularly from 7 to 12 carbon atoms, e.g., phenyloxycarbonylamino), sulfonylamino group (sulfonylamino group preferably having from 1 to 30 carbon atoms, more preferably 1 to 20 carbon atoms, particularly from 1 to 12 carbon atoms, e.g., methanesulfonylamino, benzenesulfonylamino), sulfamoyl group (sulfamoyl group preferably having from 2 to 30 carbon atoms, more preferably 2 to 20 carbon atoms, particularly from 2 to 10 carbon atoms, e.g., sulfamoyl, methylsulfamoyl, dimethylsulfamoyl, phenylsulfamoyl), carbamoyl group (carbamoyl group preferably having from 1 to 30 carbon atoms, more preferably 1 to 20 carbon atoms, particularly from 1 to 12 carbon atoms, e.g., carbamoyl,

methylcarbamoyl, diethylcarbamoyl, phenylcarbamoyl), alkylthio group (alkylthio group preferably having from 1 to 30 carbon atoms, more preferably 1 to 20 carbon atoms, particularly from 1 to 12 carbon atoms, e.g., methylthio, ethylthio), arylthio group (arylthio group preferably having from 6 to 30 carbon atoms, more preferably 6 to 20 carbon atoms, particularly from 6 to 12 carbon atoms, e.g., phenylthio), heteroarylthio group (heteroarylthio group preferably having from 1 to 30 carbon atoms, more preferably 1 to 20 carbon atoms, particularly from 1 to 12 carbon atoms, e.g., pyridylthio, 2-benzimidazolylthio, 2-benzoxazolylthio, 2-benzthiazolylthio), sulfonyl group (sulfonyl group preferably having from 1 to 30 carbon atoms, more preferably 1 to 20 carbon atoms, particularly from 1 to 12 carbon atoms, e.g., mesyl, tosyl), sulfinyl group (sulfinyl group preferably having from 1 to 30 carbon atoms, more preferably 1 to 20 carbon atoms, particularly from 1 to 12 carbon atoms, e.g., methanesulfinyl, benzenesulfinyl), ureide group (ureide group preferably having from 1 to 30 carbon atoms, more preferably 1 to 20 carbon atoms, particularly from 1 to 12 carbon atoms, e.g., ureide, methylureide, phenylureide), phosphoric acid amide group (phosphoric acid amide group preferably having from 1 to 30 carbon atoms, more preferably 1 to 20 carbon atoms, particularly from 1 to 12 carbon atoms, e.g., diethylphosphoric acid amide, phenylphosphoric acid amide), hydroxy group, mercapto group, halogen atom (e.g.,

fluorine atom, chlorine atom, bromine atom, iodine atom), cyano group, sulfo group, carboxyl group, nitro group, hydroxamic acid group, sulfinio group, hydrazino group, imino group, heterocyclic group (heterocyclic group preferably having from 1 to 30 carbon atoms, more preferably from 1 to 12 carbon atoms, and containing as hetero atoms nitrogen atom, oxygen atom and sulfur atom, e.g., imidazolyl, pyridyl, quinolyl, furyl, chenyl, piperidyl, morpholino, benzoxazolyl, benzimidazolyl, benzthiazolyl), and silyl group (silyl group preferably having from 3 to 40 carbon atoms, more preferably 3 to 30 carbon atoms, particularly from 3 to 24 carbon atoms, e.g., trimethylsilyl, triphenylsilyl). These substituents may be further substituted. R^1 's or R^2 's may be connected to each other, or R^1 and R^2 may be connected to each other to form a condensed ring structure.

[0018]

Preferred among these groups represented by R^{11} and R^{12} are alkyl group, aryl group, heteroaryl group, alkoxy group, halogen atom, cyano group, and cyclic structure obtained by the connection of R^{11} 's or R^{12} 's to own or each other. More desirable among these groups are alkyl group, aryl group, and groups which are connected to each other to form an aromatic group. Even more desirable among these groups are alkyl group, and groups which are connected to each other to form an aromatic group.

R^{13} , R^{14} and R^{15} each represent a hydrogen atom or substituent. Examples of the substituents represented by R^{13} and R^{15} include alkyl group, alkenyl group, alkynyl group, aryl group, heterocyclic group, and alkoxy group. Preferred among the groups represented by R^{13} and R^{15} are alkyl group, aryl group, and heteroaryl group. More desirable among these groups is alkyl group.

[0019]

Examples of the substituent represented by R^{14} include alkyl group, alkenyl group, alkynyl group, aryl group, heteroaryl group, heterocyclic group, and cyano group. Preferred among the groups represented by R^{14} are hydrogen atom, and alkyl group. More desirable among these groups is hydrogen atom.

The suffix m^1 represents an integer of from 0 to 4. The suffix m^2 represents an integer of from 0 to 6. When m^1 and m^2 are plural, the plurality of R^{11} 's and R^{12} 's may be the same or different. The m^1 is preferably from 0 to 2. The m^2 is preferably from 0 to 4, more preferably from 0 to 2.

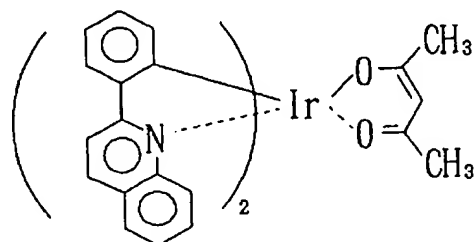
The compound of the invention may be a so-called low molecular compound having one repeating unit such as one represented by the general formula (1) or may be a so-called oligomer or polymer compound having a plurality of repeating units such as one represented by the general formula (1) (having a weight-average molecular weight (in polystyrene equivalence)

of preferably from 1,000 to 5,000,000, more preferably from 2,000 to 1,000,000, even more preferably from 3,000 to 100,000) . The compound of the invention is preferably a low molecular compound.

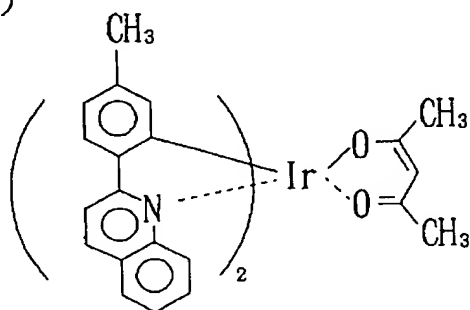
Examples of the compound of the invention will be given below, but the present invention should not be construed as being limited thereto.

[0020]

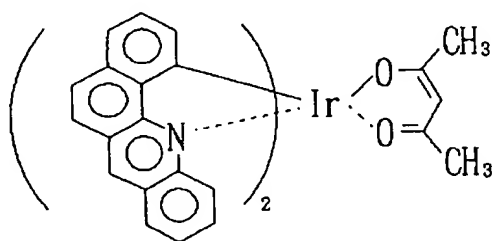
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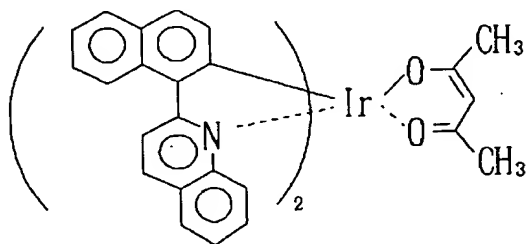
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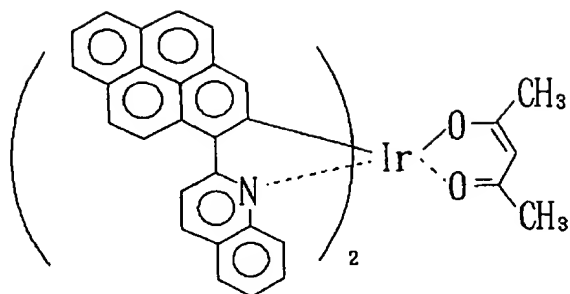


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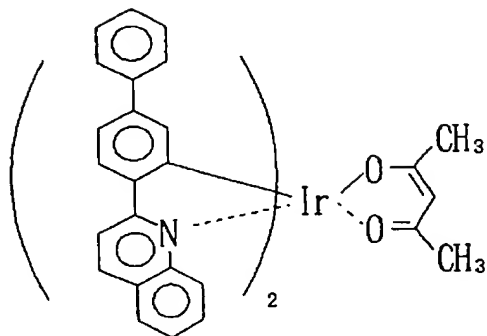


[0021]

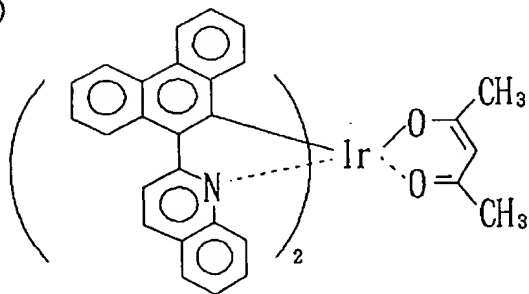
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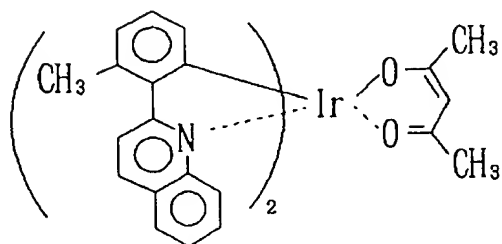
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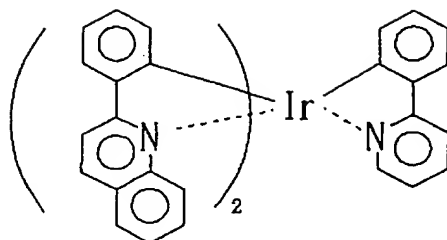


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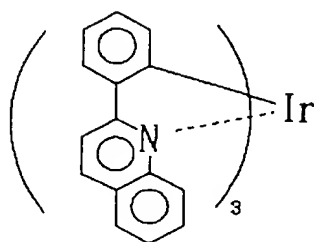


[0022]

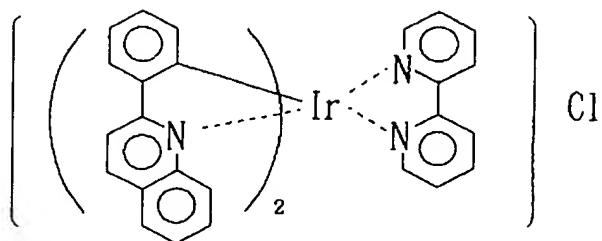
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(1-10)



(1-11)



[0023]

The synthesis of the compound of the invention can be accomplished by any proper method. For example, various ligands or dissociation products thereof and an iridium compound may be processed at room temperature or at elevated temperatures (heating by microwave, too, is effective besides normal heating) in the presence or absence of a solvent (e.g., halogen-based solvent, alcohol-based solvent, ether-based solvent, water) or in the presence or absence of a base (e.g., various organic bases such as sodium methoxide, t-butoxy potassium, triethylamine and potassium carbonate). As the starting materials there may be used iridium chloride (III), trisacetyl acetate iridium (III), potassium hexachloroiridate (III), potassium hexachloroiridate (IV), and analogues thereof.

[0024]

The light-emitting element comprising the compound of the invention will be further described hereinafter. The light-emitting element of the invention is not specifically limited in its system, driving method and form of utilization so far as it comprises the compound of the invention. In practice, however, the light-emitting element of the invention is preferably in the form of structure utilizing light emission from the compound of the invention or structure comprising the compound of the invention as a charge-transporting material. A representative example of light-emitting element is an organic

EL (electroluminescence) element.

The process for the formation of the organic layer in the light-emitting element comprising the compound of the invention is not specifically limited. In practice, however, any method such as resistively-heated vacuum evaporation method, electron beam method, sputtering method, molecular lamination method, coating method, ink jet method and printing method may be used. Preferred among these methods are resistively-heated vacuum evaporation method and coating method from the standpoint of properties and producibility.

[0025]

The light-emitting element of the invention comprises a light-emitting layer or a plurality of thin organic compound layers containing a light-emitting layer formed interposed between a pair of electrodes, i.e., cathode and anode. There may be provided a positive hole-injecting layer, a positive hole-transporting layer, an electron-injecting layer, an electron-transporting layer and a protective layer besides the light-emitting layer. These layers may be provided with other functions. The various layers may be each made of various materials.

The anode supplies a positive hole into the positive hole-injecting layer, positive hole-transporting layer, light-emitting layer, etc. The anode may be made of a metal, alloy, metal oxide, electrically-conductive compound or

mixture thereof, preferably a material having a work function of 4 eV or more. Specific examples of such a material include electrically-conductive metal oxide such as tin oxide, zinc oxide, indium oxide and indium tin oxide (ITO), metal such as gold, silver, chromium and nickel, mixture or laminate of such a metal and electrically-conductive metal oxide, electrically inorganic material such as copper iodide and copper sulfate, electrically-conductive organic material such as polyaniline, polythiophene and polypyrrole, and laminate of these materials with ITO. Preferred among these materials are electrically-conductive metal oxides. Particularly preferred among these electrically-conductive metal oxides is ITO from the standpoint of producibility, electrical conductivity and transparency. The thickness of the anode may be properly predetermined depending on its material. In practice, however, it is preferably from 10 nm to 5 μ m, more preferably from 50 nm to 1 μ m, even more preferably from 100 nm to 500 nm.

[0026]

The anode is normally used in the form of anode layer formed on soda-lime glass, non-alkali glass, transparent resin substrate or the like. As the glass, if used, there is preferably used non-alkali glass to reduce the amount of ions to be eluted therefrom. Soda-lime glass, if used, is preferably coated with a barrier such as silica. The thickness of the substrate is

not specifically limited so far as it suffices to maintain a desired mechanical strength. In practice, however, it is normally 0.2 mm or more, preferably 0.7 mm if glass is used.

The preparation of the anode may be accomplished by any method depending on the materials used. If ITO is used, for example, electron beam method, sputtering method, resistively-heated vacuum evaporation method, chemical reaction method (sol-gel method), method involving the coating of a dispersion of indium tin oxide or the like can be used to form an anode layer.

The anode can be cleaned or otherwise treated to lower the driving voltage of the element or enhance the light emission efficiency of the element. The anode made of ITO, for example, can be effectively subjected to UV-ozone treatment, plasma treatment, etc.

[0027]

The cathode supplies electron into the electron-injecting layer, electron-transporting layer, light-emitting layer, etc. The cathode is selected taking into account the adhesivity to the layer adjacent to the negative electrode such as electron-injecting layer, electron-transporting layer and light-emitting layer, ionization potential, stability, etc. As the material constituting the cathode there may be used a metal, alloy, metal halide, metal oxide, electrically-conductive compound or

mixture thereof. Specific examples of such a material include alkaline metal (e.g., Li, Na, K), fluoride thereof, alkaline earth metal (e.g., Mg, Ca), fluoride thereof, gold, silver, lead, aluminum, sodium-potassium alloy, mixture thereof, lithium-aluminum alloy, mixture thereof, magnesium-silver alloy, mixture thereof, and rare earth metal such as indium and ytterbium. Preferred among these materials are those having a work function of 4 eV or less. Even more desirable among these materials are aluminum, lithium-aluminum alloy, mixture thereof, magnesium-silver alloy, and mixture thereof. The cathode may be not only in the form of single layer structure comprising the foregoing compound or mixture but also in the form of laminated structure comprising the foregoing compound or mixture. For example, a laminated structure of aluminum/lithium fluoride or aluminum/lithium oxide is preferred. The thickness of the cathode may be properly predetermined depending on its material. In practice, however, it is preferably from 10 nm to 5 μm , more preferably from 50 nm to 1 μm , even more preferably from 100 nm to 1 μm .

The preparation of the cathode can be accomplished by any method as electron beam method, sputtering method, resistively-heated vacuum evaporation method and coating method. A single metal may be vacuum-vaporized. Alternatively, two or more components may be vacuum-vaporized at the same time. Further, a plurality of metals may be

vacuum-vaporized to form an alloy electrode. Alternatively, an alloy which has been previously prepared may be vacuum-vaporized.

The sheet resistivity of the anode and cathode is preferably as low as possible and thus is preferably hundreds of ohm/□ or less.

[0028]

As the material constituting the light-emitting layer there may be used any material which can form a layer capable of injecting positive hole from the anode, positive hole-injecting layer or positive hole-transporting layer as well as injecting electron from the cathode, electron-injecting layer or electron-transporting layer during the application of electric field, moving electron thus injected or providing a site for the recombination of positive hole and electron for emission of light. Alternatively, any material which emits light from either singlet exciton or triplet exciton may be used. Examples of the light-emitting material employable herein include various metal complexes such as metal complex and rare earth complex of benzoxazole derivative, benzoimidazole derivative, benzothiazole derivative, styrylbenzene derivative, polyphenyl derivative, diphenylbutadiene derivative, tetraphenylbutadiene derivative, naphthalimide derivative, coumarine derivative, perylene derivative, perynone derivative, oxadiazole

derivative, aldazine derivative, pyralidine derivative, cyclopentadiene derivative, bisstyrylanthracene derivative, quinacridone derivative, pyrrolopyridine derivative, thiadiazolopyridine derivative, cyclopentadiene derivative, styrylamine derivative, aromatic dimethylidine compound and 8-quinolinol derivative, polymer compound such as polythiophene, polyphenylene and polyphenylenevinylene, organic silane derivative, and the compound of the invention. The thickness of the light-emitting layer is not specifically limited but is normally from 1 nm to 5 μm , preferably from 5 nm to 1 μm , even more preferably from 10 nm to 500 nm.

The process for the formation of the light-emitting layer is not specifically limited. In practice, however, any method such as resistively-heated vacuum evaporation method, electron beam method, sputtering method, molecular lamination method, coating method (e.g, spin coating method, casting method, dip coating method), ink jet method, LB method and printing method may be used. Preferred among these methods are resistively-heated vacuum evaporation method and coating method.

[0029]

As the material constituting the positive hole-injecting layer and positive hole-transporting layer there may be used any material having any of capability of injecting positive hole from the anode, capability of transporting positive hole

and capability of giving barrier to electron injected from the cathode. Specific examples of such a material include electrically-conductive polymer oligomers such as carbazole derivative, triazole derivative, oxazole derivative, oxadiazole derivative, imidazole derivative, polyaryllalkane derivative, pyrazoline derivative, pyrazolone derivative, phenylenediamine derivative, arylamine derivative, amino-substituted chalcone derivative, styrylanthracene derivative, fluorenone derivative, hydrazone derivative, stilbene derivative, silazalane derivative, aromatic tertiary amine compound, styrylamine compound, aromatic dimethylidene compound, porphyrin compound, polysilane compound, poly(N-vinylcarbazole) derivative, aniline copolymer, thiophene oligomer and polythiophene, organic silane derivative, carbon film, and the compound of the invention. The thickness of the positive hole-injecting layer and positive hole-transporting layer is not specifically limited but is preferably from 1 nm to 5 μm , more preferably from 5 nm to 1 μm , even more preferably from 10 nm to 500 nm. The positive hole-injecting layer and positive hole-transporting layer each may be in the form of single layer structure made of one or more of the foregoing material or multi-layer structure consisting of a plurality of layers having the same or different compositions.

The formation of the positive hole-injecting layer and

positive hole-transporting layer can be accomplished by any method such as vacuum evaporation method, LB method, method involving the coating of a solution or dispersion of the foregoing positive hole-injecting or transporting material in a solvent (e.g., spin coating method, casting method, dip coating method), ink jet method and printing method. In the case of coating method, the foregoing positive hole-injecting or transporting material may be dissolved or dispersed in a solvent with a resin component. Examples of such a resin component include polyvinyl chloride, polycarbonate, polystyrene, polymethyl methacrylate, polybutyl methacrylate, polyester, polysulfone, polyphenylene oxide, polybutadiene, poly(N-vinylcarbazole), hydrocarbon resin, ketone resin, phenoxy resin, polyamide, ethyl cellulose, vinyl acetate, ABS resin, polyurethane, melamine resin, unsaturated polyester resin, alkyd resin, epoxy resin, and silicon resin.

[0030]

As the material constituting the electron-injecting material layer and electron-transporting layer there may be used any material having any of capability of injecting electron from the cathode, capability of transporting electron and capability of giving barrier to positive hole injected from the anode. Specific examples of such a material include various metal complexes such as metal complex of heterocyclic tetracarboxylic anhydride such as triazole derivative, oxazole

derivative, oxadiazole derivative, fluorenone derivative, anthraquinodimethane derivative, anthrone derivative, diphenylquinone derivative, thiopyranedioxide derivative, carbodiimide derivative, fluorenilidenemethane derivative, distyrylpyrazine derivative and naphthaleneperylene, phthalocyanine derivative and 8-quinolinol derivative and metal complex comprising metal phthalocyanine, benzoxazole or benzothiazole as a ligand, and organic silane derivative. The thickness of the electron-injecting layer and electron-transporting layer is not specifically limited but is preferably from 10 nm to 500 nm, more preferably from 5 nm to 1 μ m, even more preferably from 10 nm to 500 nm. The electron-injecting layer and electron-transporting layer each may be in the form of single layer structure made of one or more of the foregoing material or multi-layer structure consisting of a plurality of layers having the same or different compositions.

The formation of the electron-injecting layer and electron-transporting layer can be accomplished by any method such as vacuum evaporation method, LB method, method involving the coating of a solution or dispersion of the foregoing positive hole-injecting or transporting material in a solvent (e.g., spin coating method, casting method, dip coating method), ink jet method and printing method. In the case of coating method, the foregoing positive hole-injecting or transporting material

maybe dissolved or dispersed in a solvent with a resin component.

As the resin component there may be used any of those exemplified with reference to the positive hole-injecting or transporting layer.

[0031]

As the material constituting the protective layer there may be used any material capable of preventing materials which accelerating the deterioration of the element such as water content and oxygen from entering into the element. Specific examples of such a material include metal such as In, Sn, Pb, Au, Cu, Ag, Al, Ti and Ni, metal oxide such as MgO, SiO, SiO₂, Al₂O₃, GeO, NiO, CaO, BaO, Fe₂O₂, Y₂O₃ and TiO₂, metal fluoride such as MgF₂, LiF, AlF₃ and CaF₂, polyethylene, polypropylene, polymethyl methacrylate, polyimide, polyurea, polytetrafluoroethylene, polychlorotrifluoroethylene, polydichlorofluoroethylene, polymer of chlorotrifluoroethylene with dichlorodifluoroethylene, copolymer obtained by the copolymerization of tetrafluoroethylene with a monomer mixture comprising at least one comonomer, fluorine-containing copolymer having a cyclic structure in the copolymer main chain, water-absorbing material having a water absorption of 1% or more, and moisture-resistant material having a water absorption of 0.1% or less.

The process for the formation of the protective layer is not specifically limited. Examples of the method employable

herein include vacuum evaporation method, sputtering method, reactive sputtering method, MBE (molecular beam epitaxy) method, cluster ion beam method, ion plating method, plasma polymerization method (high frequency excited ion plating method), plasma CVD method, laser CVD method, heat CVD method, gas source CVD method, coating method, and printing method.

[0032]

[Example]

Specific embodiments of implication of the invention will be described hereinafter, but the present invention should not be construed as being limited thereto.

(Synthesis Example 1)

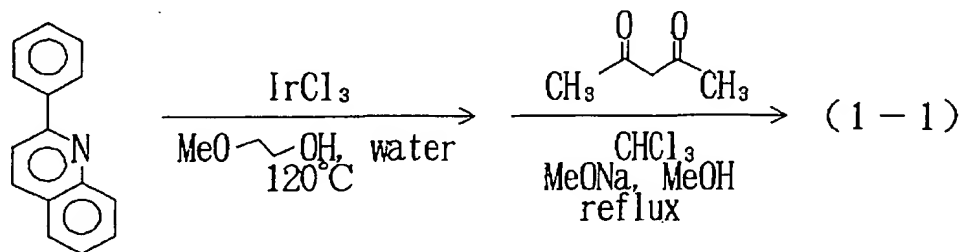
Synthesis of Compound (1-1)

1 g of 2-phenylquinoline, 0.71 g of iridium chloride (III), 40 ml of 2-methoxy ethanol and 10 ml of water were mixed. The mixture was then stirred at a temperature of 120°C in a stream of nitrogen for 6 hours. The mixture was then cooled to room temperature. To the mixture was then added 50 ml of a 1 N aqueous solution of hydrochloric acid. The solid thus precipitated was then withdrawn by filtration. The solid thus withdrawn was then purified through silica gel column chromatography (chloroform) to obtain a reddish brown solid. 0.1 g of the reddish brown solid, 0.08 g of acetyl acetone, 0.15 ml of a 28 wt-% methanol solution of sodium methoxide and 30 ml of chloroform were then mixed. The mixture was then heated under

reflux for 3 hours. The mixture was then cooled to room temperature. The reaction solution was then purified through silica gel column chromatography (chloroform) to obtain 0.08 g of a red solid (1-1).

[0033]

Synthesis of Compound (1-1)



[0034]

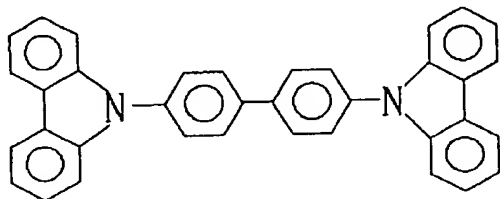
COMPARATIVE EXAMPLE 1

α -NPD (N,N'-diphenyl-N,N'-di(α -naphthyl)-benzidine) was vacuum-evaporated onto an ITO substrate which had been cleaned to a thickness of 40 nm. The following compounds A and B were then simultaneously vacuum-evaporated onto the substrate at a ratio of 10 : 1 to a thickness of 24 nm. The compound C was then vacuum-evaporated onto the metal deposit. A patterned mask (arranged such that the light-emitting area was 4 mm x 5 mm) was then disposed on the thin organic layer. Magnesium and silver were then simultaneously vacuum-evaporated onto the thin organic layer at a ratio of

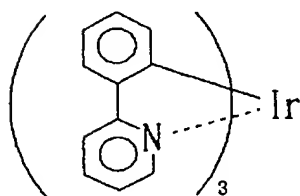
10 : 1 to a thickness of 250 nm in a vacuum metallizer. Silver was then vacuum-evaporated onto the metal deposit to a thickness of 50 nm. Using a Type 2400 source measure unit produced by TOYO TECHNICA CO., LTD., a dc constant voltage was then applied to the EL element thus prepared to cause the emission of light which was then measured for luminance and wavelength by means of a Type BM-8 luminance meter produced by TOPCON CORP. and a Type PMA-11 spectral analyzer produced by Hamamatsu Photonics Co., Ltd., respectively. As a result, it was found that green light having λ_{max} of 516 nm and CIE chromaticity value (x, y) of 0.29 and 0.62 had been emitted. The external quantum efficiency was 13.6% (478 cd/m²).

[0035]

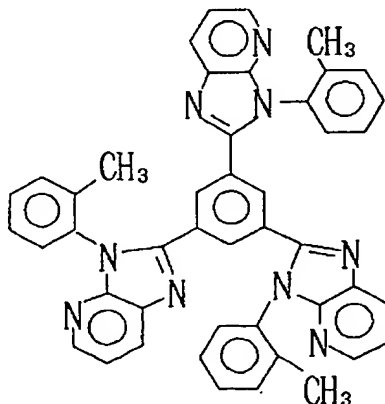
Compound A



Compound B



Compound C



[0036]

COMPARATIVE EXAMPLE 2

α -NPD (N,N'-diphenyl-N,N'-di(α -naphthyl)-benzidine) was vacuum-evaporated onto an ITO substrate which had been cleaned to a thickness of 40 nm. Alq (trisquinonate aluminum) and DCM(4-(Dicyanomethylene)-2-methyl-6-(4-dimethylamino styryl)-4H-pyran) were then simultaneously vacuum-evaporated onto the substrate at a ratio of 100 : 1 to a thickness of 60 nm. The substrate was then cathodically vacuum-metallized in the same manner as in Comparative Example 1 to prepare an element. As a result, reddish orange-colored light having λ_{\max} of 597 nm and CIE chromaticity value (x, y) of 0.54 and 0.44 had been emitted. The external quantum efficiency was 0.89% (248 cd/m²). The half width of emission spectrum was 92 nm.

[0037]

EXAMPLE 1

An element was prepared in the same manner as in Comparative Example 1 except that the compound (1-1) was used instead of the compound B. As a result, red light having λ_{\max} of 599 nm and CIE chromaticity value (x, y) of 0.60 and 0.39 had been emitted. The external quantum efficiency was 13.4% (252 cd/m²). The half width of emission spectrum was 69 nm. As above, by using the compound of the invention, red light having a high external quantum efficiency and high purity of color can be obtained.

[0038]

EL elements comprising compounds of the invention can be prepared and evaluated in the same manner as mentioned above. Thus, high efficiency red light-emitting elements can be prepared. And, a coating-type high efficiency red light-emitting element comprising the compound of the invention dispersed in an unconjugated polymer such as poly(vinylcarbazole) or a conjugated polymer such as poly(fluorene) compound can also be prepared.

[0039]

[Effect of the Invention]

The high efficiency red light-emitting element according to the invention has a higher efficiency than the conventional red light-emitting elements. Thus, the high efficiency red light-emitting element according to the invention is suitable for various arts such as display element, display, backlight, electrophotography, illuminating light source, recording light source, exposure light source, reading light source, sign, advertising display and interior. The high efficiency red light-emitting element according to the invention can consume a drastically reduced power as compared with the conventional red light-emitting organic EL elements having an external quantum yield of less than 5%. The high efficiency red light-emitting element according to the invention can also have an increased working area and be used over an extended period

of time. Thus, the high efficiency red light-emitting element according to the invention can find wider application in the art of organic EL color display.

The compound of the invention can be used for medical use or as fluorescent brightening agent, photographic material, UV-absorbing material, laser dye, color filter dye, color conversion filter, etc.

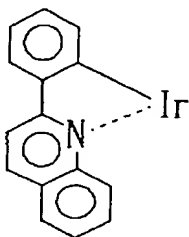
[Designation of Document] Abstract

[Abstract]

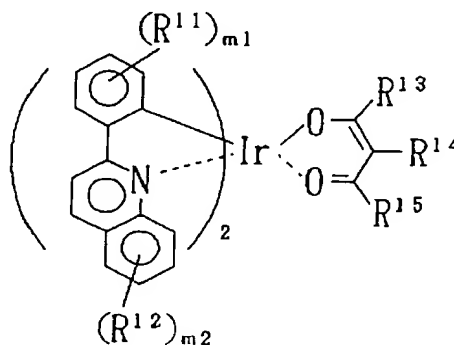
[Problem] To provide a red light-emitting element having excellent light-emitting properties and a material which can form such a red light-emitting element.

[Means for Resolution] To use an organic light-emitting element having an external quantum efficiency of 5% or more and λ_{max} of 590 nm or more and comprising a compound having a partial structure represented by the following general formula (1). Preferably, a compound represented by the following general formula (2) is used.

(1)



(2)



[Selected diagram] None